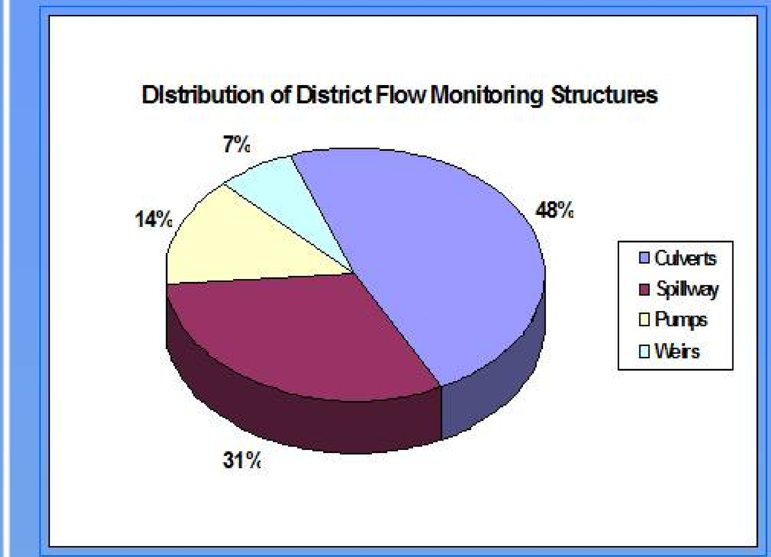
Flow Measurement and Instrumentation at Culverts

Introduction

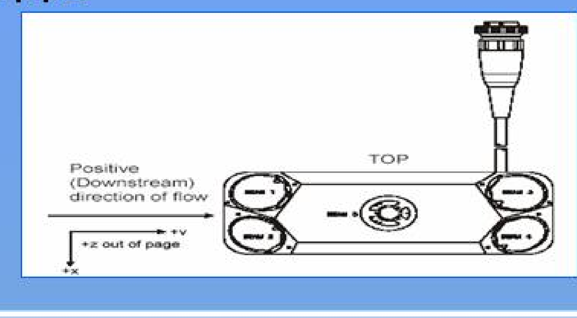


The largest number of flow monitoring structures at the District are Culvert structures. Many of these structures are perpendicular to flow-ways and not conducive for streamgauging with conventional Doppler instruments like the ADCP. Further, many of them have short flow-ways and flows are not fully developed for stream gauging. Alternative methods or instruments are needed for measuring flows at culvert-type structures. The Acoustic Doppler flow meter (ADFM) manufactured by MGD Technologies, Inc. is capable of collecting the large amounts of flow measurements with the accuracy needed for calibrating culverts operating under free-surface flow and pressurized conditions.

Flow Measurement Instrumentation

ADFM Transducer and signal processing unit

The ADFM is a flow meter based on pulse Doppler technology capable of measuring a velocity profile. The instrumentation consists of a transducer mounted in the flow, a signal processing unit, and an interface cable. Four narrow acoustic beams are used to accurately measure the horizontal velocity in the channel or culvert. A fifth beam measures the depth in the channel. The instruments is capable of measuring open channel or closed conduit flow in a pipe.



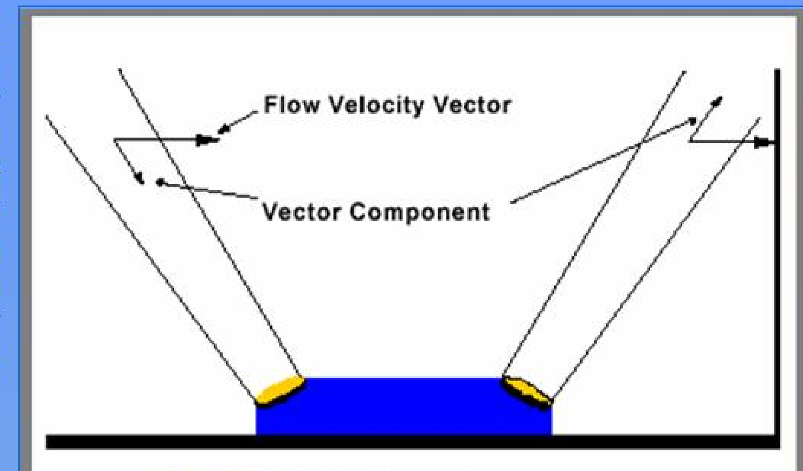
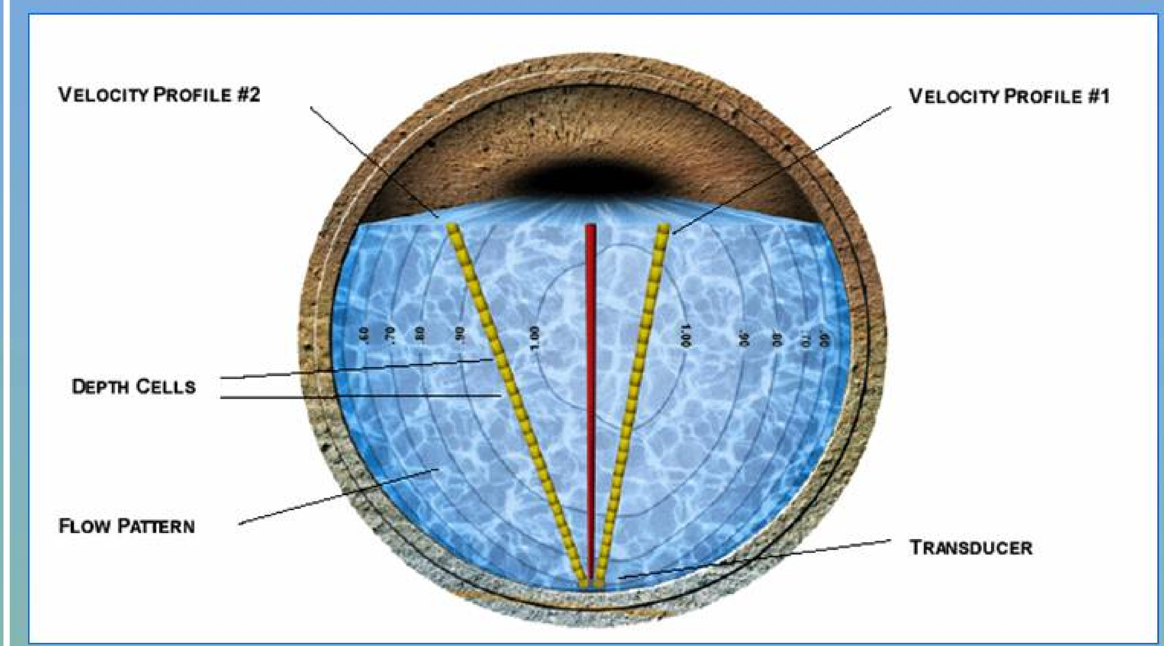


FIGURE 2 - ADFM BEAM GEOMETRY

ADFM Principles of Operation



A transducer assembly is mounted on the invert of the pipe or channel. The transducer emits short pulses which are backscattered by the materials suspended in the flow. The echoes are Doppler shifted in frequency and this shift is proportional to the speed. The return signal is divided into discrete intervals corresponding to different depths in flow.

Velocities measured in small volumes called depth cells and averaged for the whole cross section of the culvert.

Velocities from one beam pair are averaged to generate profile #1

Velocities from the beam pair on the opposite side are averaged to generate profile #2

The total discharge is calculated from these averages and the cross-section area in the culvert.

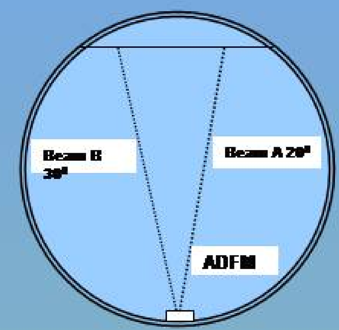
The ADFM can make continuous measurements at a site and as the hydraulic conditions change, the change will manifest itself in the distribution of velocity throughout the depth of flow.

ADFM Discharge Algorithm

$$Q = kA\frac{(V_A + V_B)}{2}$$

$$V_A = (\overline{v_{b1}} - \overline{v_{b3}})/2Sin(20^o)$$

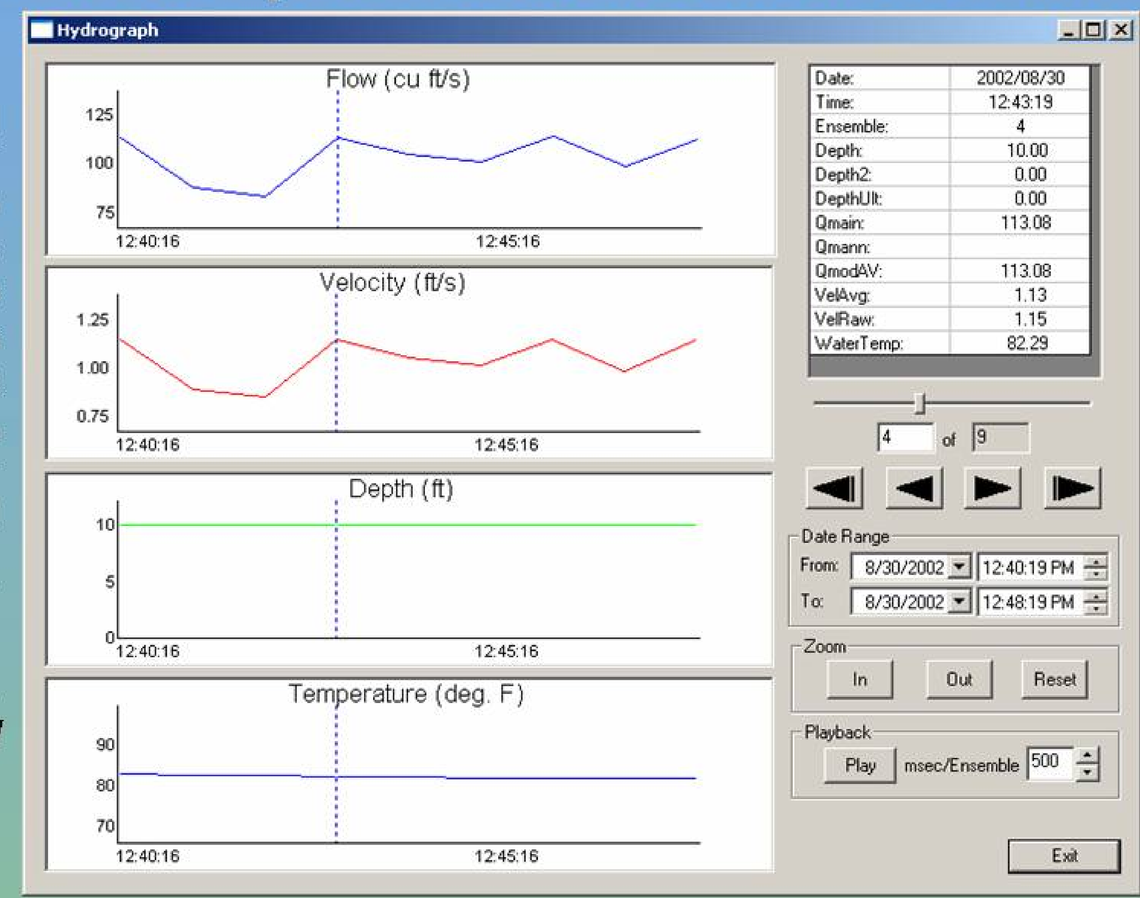
$$V_B = (\overline{v_{b2}} - \overline{v_{b4}})/2Sin(30^o)$$



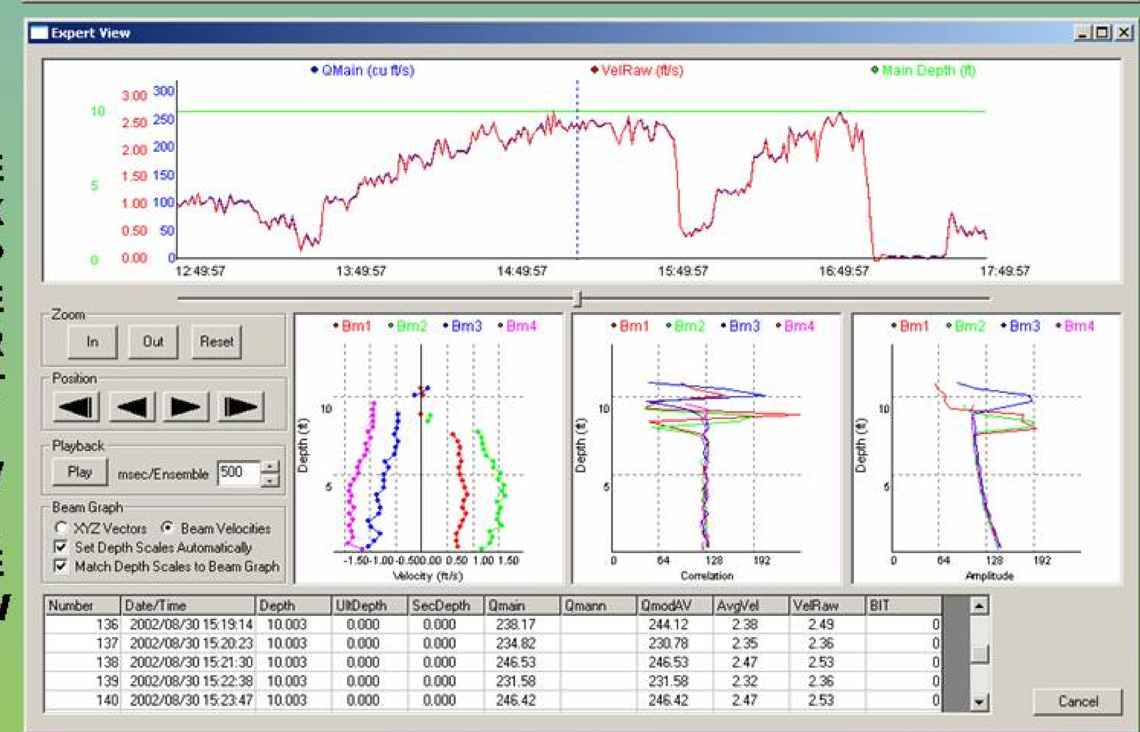
where V_A and V_B are the beam pair average velocities, A is the cross-section area, and the bars over v_{b1}, v_{b2}, v_{b3}, v_{b4} indicate average bin (1-17) velocities

Screen captures from the Win ADFM software

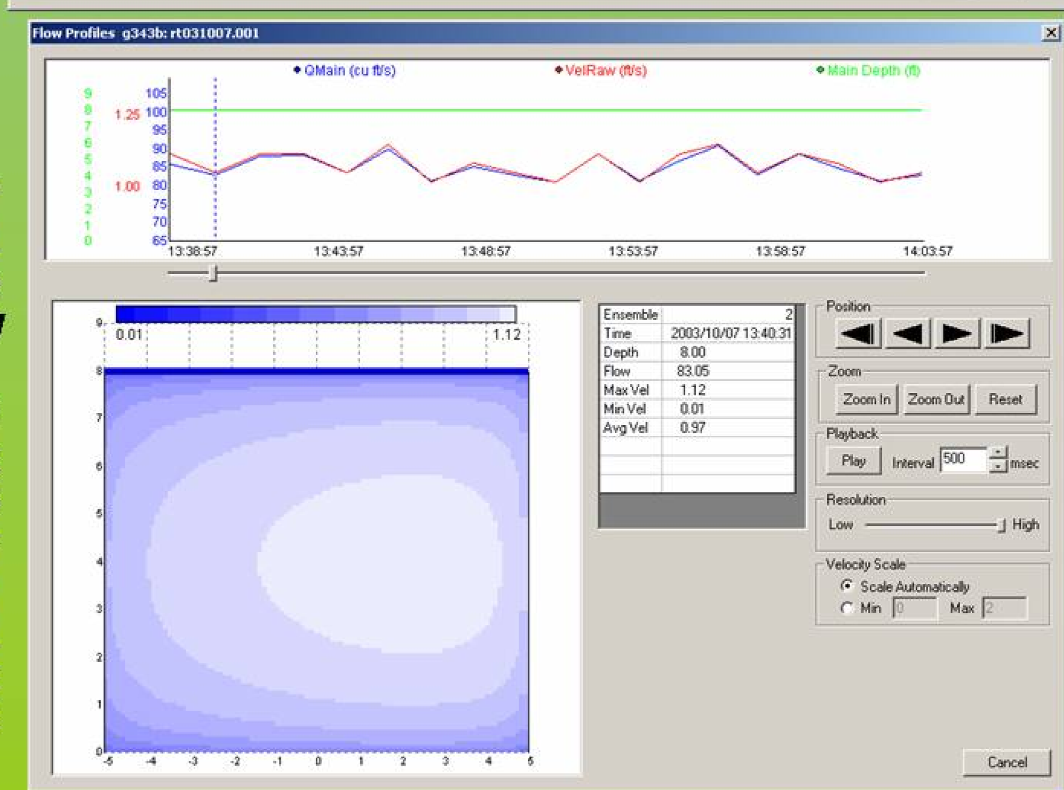
HYDROGRAPH VIEW



EXPERT VIEW



FLOW PROFILES



ADFM deployments in STAs

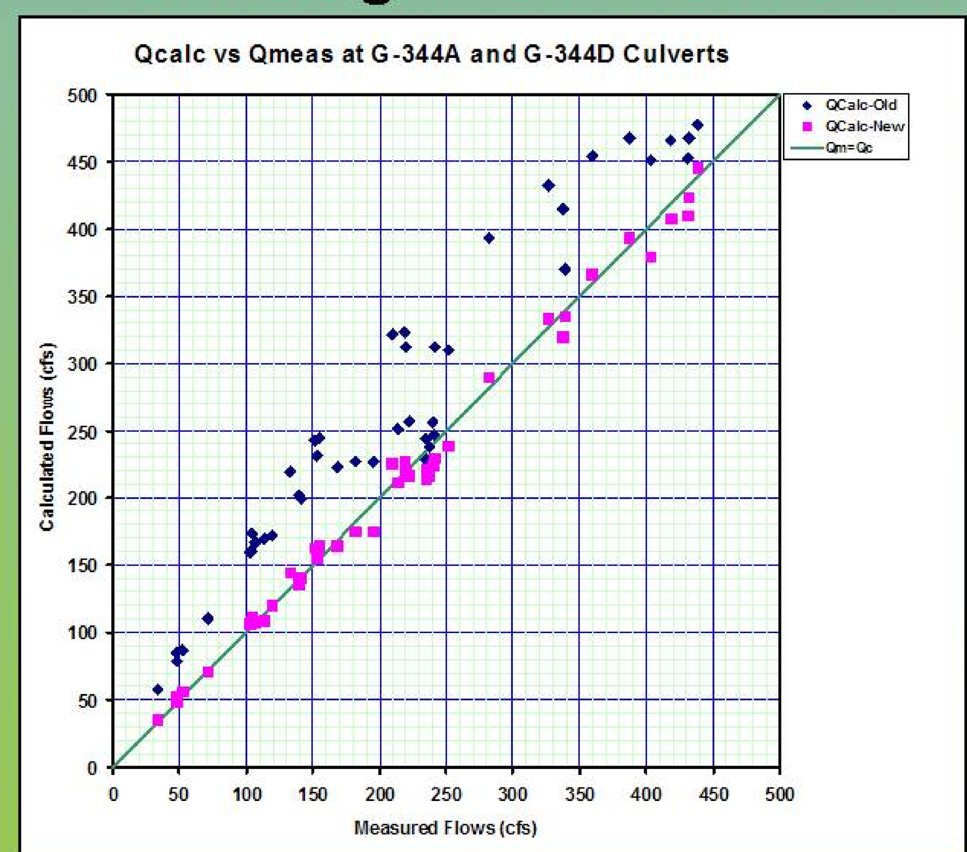
ADFM used at the G344D box culvert in STA-5 attached to an L clamp.

The ADFM was mounted using the L clamp on the crown of the culvert at G344D looking down.

The ADFM mounted at the G329A culvert in STA2 using a specialized clamp and leveling options.

The ADFM deployed at G330B in STA2

ADFM Discharge data used for improving Flow Ratings at Culverts in STA5



Previous ratings at the outflow culverts in STA-5 where overestimating the outflows. Use of the data collected using an ADFM at the culverts G344A and G344D resulted in an improved flow rating which did not overestimate the outflows.

Prepared for Hydrology & Hydraulics
Environmental Monitoring & Assessment Dept.
By Sashi Nair
February 14, 2004